Venus Rocks Petrogenesis As Constrained by K, U and Th Data

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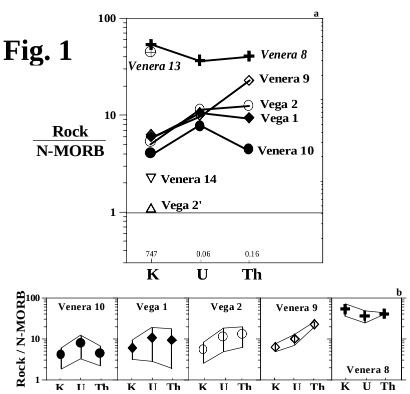
Relative to Earth's N-MORB all of four K-U-Th measured basaltic rocks of Venus are moderately enriched in all of these incompatible elements and similar to each other, but differ from the highly enriched Venera 8 material, in their U>K trend. The K-U-Th pattern for the Venera 8 material might be controlled by 1-2% partial melting of eclogitic N-MORB-like tholeite. But the Venus basalts could be apparently produced by neither crystallization of N-MORB-type magma, nor contamination of that magma by the Venera 8 material, nor batch partial melting of eclogitic N-MORB-like tholeite or primitive mantle. This might suggest unusual composition of the basalt source(s) and/or unusual fractionation process(es) on Venus.

INTRODUCTION. In Earth's petrogenetic studies, N-MORB normalized abundances of incompatible elements are compared. N-MORB is derived from the mantle depleted in such elements relative to putative Earth's primitive mantle (assumed unfractionated chondrite-like material of the bulk silicate part of Earth); the depleted mantle is attributed to be a residue of primitive mantle after silicate melt extraction, both for Earth[1] and for Venus[2]. However, the K, U and Th abundances in the Venus mantle and, hence, in N-MORB-like melts are unknown. They adopted here as equal to the corresponding Earth's values. This is not necessary, but a possible case.

DATA PRESENTATION. Spider diagrams (Fig. 1) are used to summarize K, U and Th abundances in the measured Venus rocks[3] relative to Earth's average fresh N-MORB[4]. Fig.1b demonstrates analytical errors. Two important observations of the pattern in Fig.1 are:

Fig. 1



- All of five K-U-Th measured rocks on Venus are enriched relative to N-MORB in all of these incompatible elements.

- All of the moderately enriched rocks (Venera 9, 10 and Vega 1, 2), referred to as tholeitic basalts in composition[5], are similar to each other, but differ from the highly enriched rock (Venera 8), in showing U>K trend. Within 2 standards (Fig.1b), probability of the opposite trend, K-2s/U+2s ratio, could be roughly estimated of as low as 0.0025.

This K-U-Th enrichment pattern may impose constraints on the petrogenetic processes on Venus.

END-MEMBER PROCESSES under consideration are: Intracrustal contamination of magma by highly enriched crustal material within the crust; Fractional crystallization of magma; Partial melting of the magma source; Recycling of material enriched upon fractionation on the surface into the magma source.

Crustal contamination. If assume that the magmas of the moderately enriched basaltic rocks were derived from the depleted mantle, like N-MORB, and then contaminated by the highly enriched (Venera 8) material within the crust, the contaminated magma would inherit K-U and U-Th relations from the highly enriched material. However, the Venera 8 rock shows the trend K>U while basaltic rocks - U>K (Fig.1a), which is an evidence against such a model. One can not exclude that the enriched character of these basaltic materials could be related to enriched nature of their source(s).

Intracrustal fractional crystallization of magma has been recognized to increase the K, U and Th enrichment levels but have little effect on their fractionation - on the shape of the K-U-Th pattern[6]. As an example, oceanic island-arc evolved rocks are known to be the intracrustal derivatives of parental basaltic magma. Fig.2 (data from[7]) illustrates that the K-U-Th pattern for the evolved rocks resembles those for the basalts. If so, the K-U trend differences we see in Fig.1a indicate that the highly enriched Venera 8 rock cannot be evolved from magma of any of the moderately enriched basalts, and these basalts cannot be crystallized from the depleted mantle-derived N-MORB-type magma.

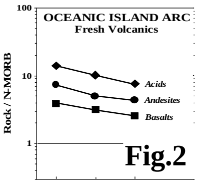


Fig.2

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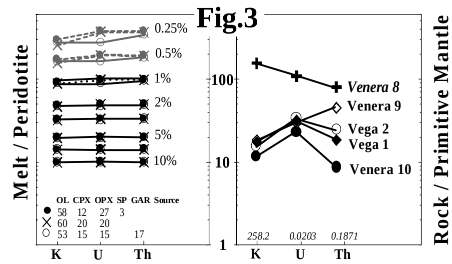
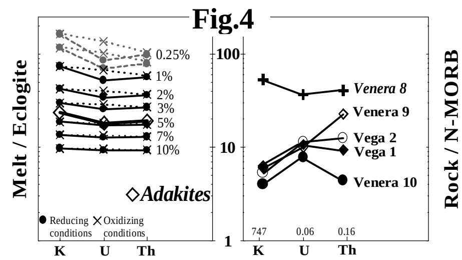
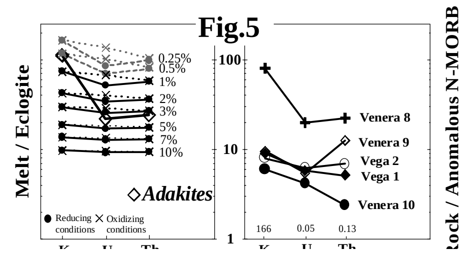
Partial melting of the magma source. The partitioning of K, U and Th between mineral and melt were calculated, based on compiled experimental data for 1 to 36 kbar[8], for two sources proposed by Hess and Head[2] - primitive mantle[9] and eclogitic tholeitic basalt. Models assume equilibrium or batch melting and remain source mineralogy and degree of melting as variables. **Fig.3** shows that the pattern for any of the measured Venus rocks is quite different in shape from the calculated pattern for partial melts produced under possible mineral ratios in lherzolite and reasonable degrees of melting of the primitive mantle. Therefore it seems highly unlikely that K-U-Th fractionation of any of these Venus rocks can be controlled by melting of the primitive mantle. The pattern in **Fig.4** confirms genesis of adakites - natural eclogite-derived partial melts - as 3-5% melts from eclogitic tholeite[10]. The Venera 8 material is seen to be similar to calculated 1-2% partial melts from eclogite in both K-U-Th pattern and enrichment level. But the basalts still differ from the model in their opposite U-K trend and lower levels of the enrichment. Average fresh N-MORB[4] gives K/(U/10[4]) ratio value of 1.2. In **Fig.5,** N-MORB sample with the ratio value of 0.3, the lowest for the fresh N-MORBs[4], is used for normalizing. Here the adakites are dissimilar to any calculated eclogite-derived partial melt in their K-U-Th pattern. Instead, the Venus basalts become similar to calculated 0.2=0.5% partial melts in the K>U trend. These low degrees of melting require, however, the enrichment level of almost one order of magnitude higher than those observed. So it appears highly unlikely a derivation of these moderately enriched basalts from eclogitic N-MORB-like tholeite.







Recycling of material fractionated on surface back into the magma source. On Venus, powerful exogenic chemical fractionation process such as water migration on Earth, is not known to exist. In such an environment, the basalt residing on the surface should subduct with approximately the same composition as it had when it erupted. This is a dead end. It is not excluded, however, that the absence of water migration on Venus might make more discernible the chemical effect of exogenic impact-induced fractionation. The trend U>K is seen in the K-U-Th enrichment pattern (Fig.6) for the laboratory impact-vapor condensate after light-gas-gun evaporation of granite target[11]. Unfortunately, K, U and Th were analyzed in only that run.

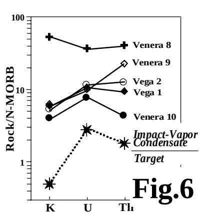


Fig.6

CONCLUSIONS. Above considerations of basic petrogenetic processes on Venus assumed the terrestrial K, U and Th abundances in the Venus primitive mantle and N-MORB-like melts. This approach made it possible to find a possible formation process for the highly enriched Venera 8 rock, but not for four moderately enriched basalts. This might raise the question of unusual composition of the basalt source(s) and/or unusual fractionation process(es) on Venus.

Acknowledgment: I am grateful to A.Ariskin for sharing his code for calculations.

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